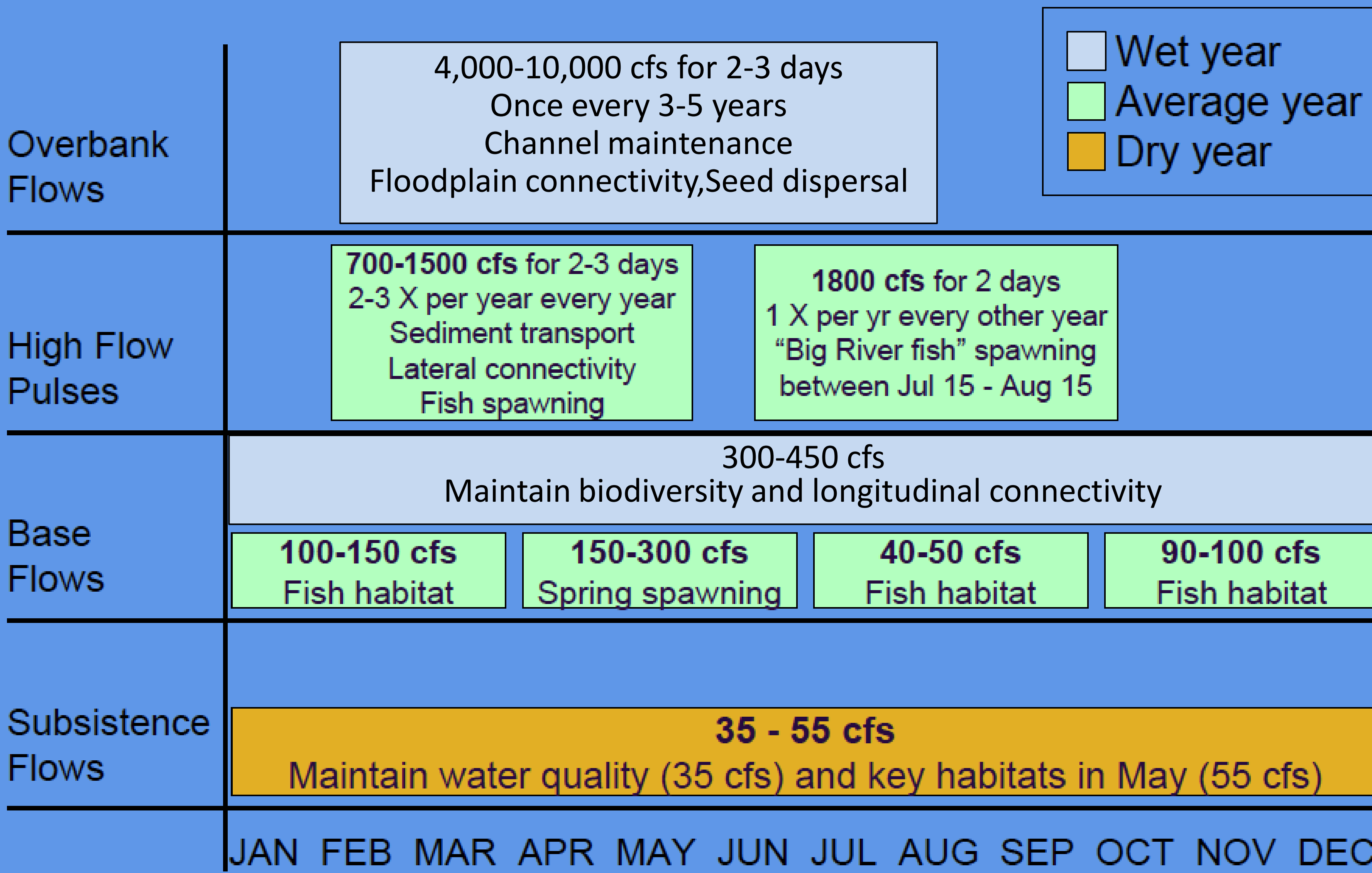
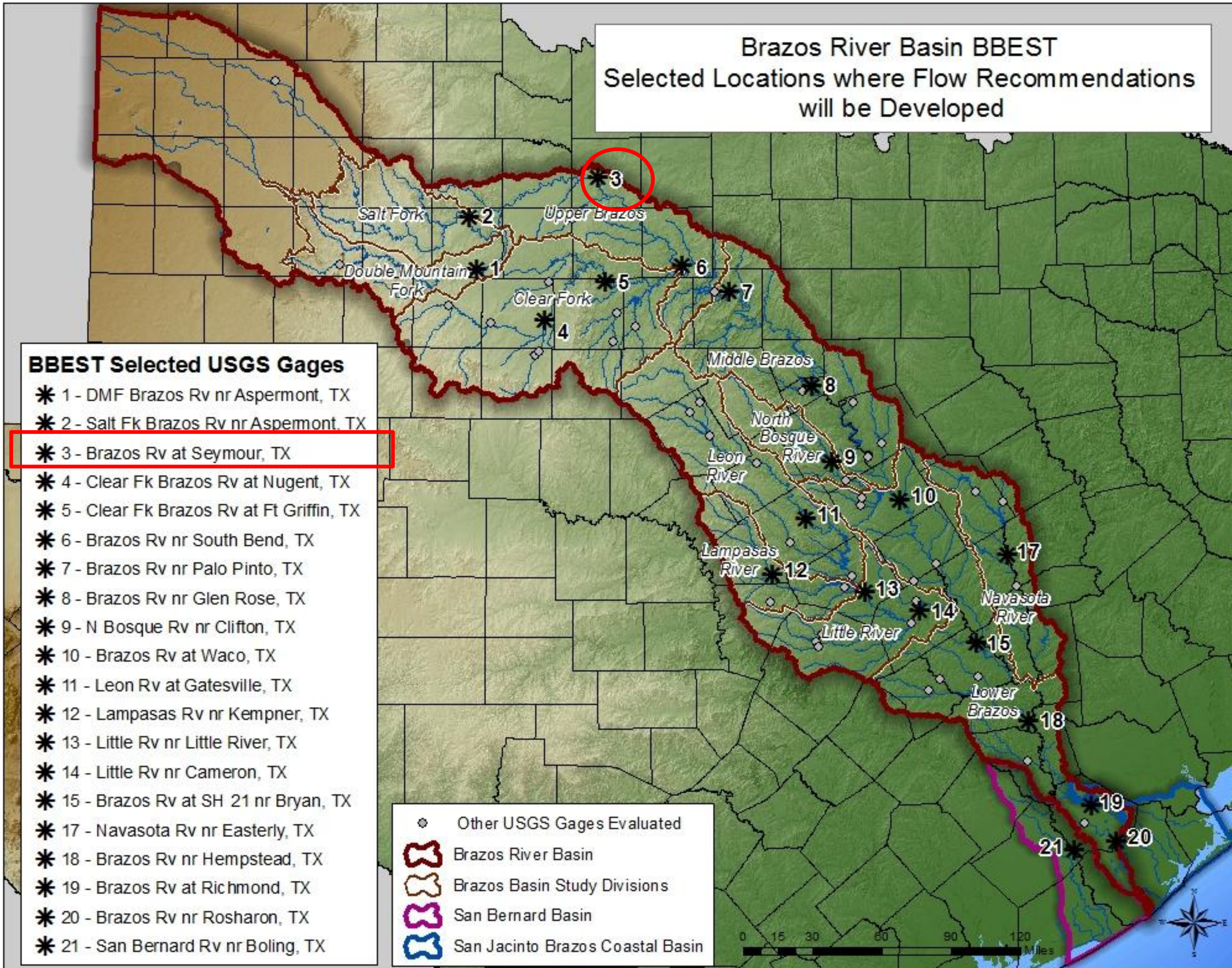
Brazos River Basin and Bay Expert Science Team Environmental Flow Regime Recommendations Report

Final Submission to the
Brazos River Basin and Bay Area Stakeholder Committee,
Environmental Flows Advisory Group,
and the Texas Commission on Environmental Quality

Sample Instream Flow Matrix




Brazos River Basin BBEST
Selected Locations where Flow Recommendations will be Developed
BBEST Selected USGS Gages
1 - DMF Brazos Rv nr Aspermont, TX
2 - Salt Fk Brazos Rv nr Aspermont, TX
3 - Brazos Rv at Seymour, TX
4 - Clear Fk Brazos Rv at Nugent, TX
5 - Clear Fk Brazos Rv at Ft Griffin, TX
6 - Brazos Rv nr South Bend, TX
7 - Brazos Rv nr Palo Pinto, TX
8 - Brazos Rv nr Glen Rose, TX
9 - N Bosque Rv nr Clifton, TX
10 - Brazos Rv at Waco, TX
11 - Leon Rv at Gatesville, TX
12 - Lampasas Rv nr Kempner, TX
13 - Little Rv nr Little River, TX
14 - Little Rv nr Cameron, TX
15 - Brazos Rv at SH 21 nr Bryan, TX
17 - Navasota Rv nr Easterly, TX
18 - Brazos Rv nr Hempstead, TX
19 - Brazos Rv at Richmond, TX
20 - Brazos Rv nr Rosharon, TX
21 - San Bernard Rv nr Boling, TX
Other USGS Gages Evaluated
Brazos River Basin
Brazos Basin Study Divisions
San Bernard Basin
San Jacinto Brazos Coastal Basin
Salt Fork
Upper Brazos
Double Mountain Fork
Clear Fork
Middle Brazos
North Bosque River
Leon River
Lampasas River
Little River
Navasota River
Lower Brazos
0 15 30 60 90 120
Miles

Upper Brazos River (confluence of Salt Fork and Double Mountain Fork to Possum Kingdom Lake): High fish assemblage integrity: dominated by a few, fluvial specialist taxa that are adapted to the variable and sometime extreme conditions of this region.

October 18, 2007, 51 cfs – upstream (left), downstream (right)

July 6, 2011, Subsistence 0.02 cfs – upstream (left), downstream (right)

Upper Brazos River (confluence of Salt Fork and Double Mountain Fork to Possum Kingdom Lake): High fish assemblage integrity: dominated by a few, fluvial specialist taxa that are adapted to the variable and sometime extreme conditions of this region.

sharpnose shiner

October 18, 2007, 51 cfs – upstrea

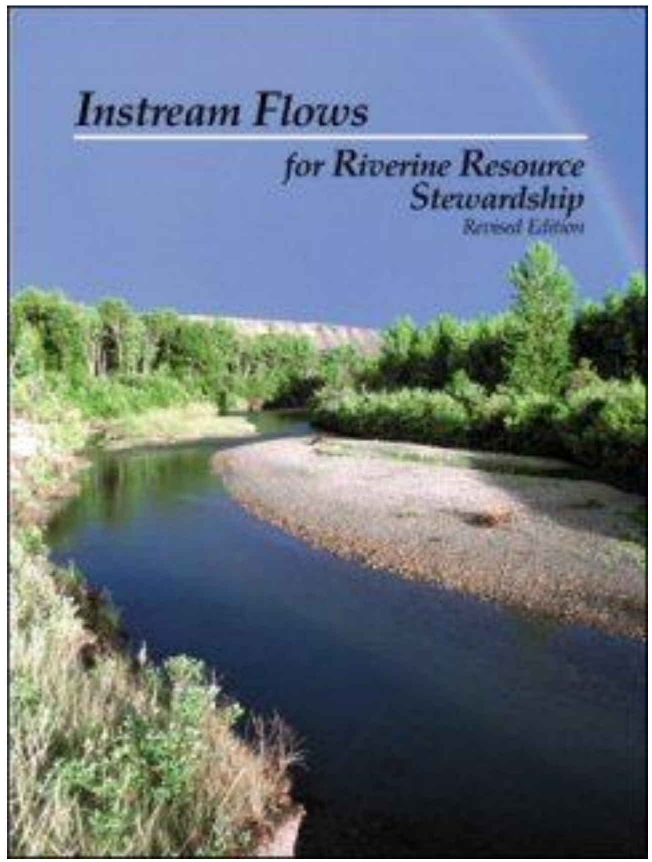
smalleye shiner

Photos from Chad Thomas. Texas State Univ.

July 6, 2011, Subsistence 0.02 cfs – upstream (left), downstream (right)

Annear, T. I. Chisholm, H. Beecher, A. Locke, and 12 other authors. 2004. *Instream Flows for Riverine Resource Stewardship, Revised Edition*. Instream Flow Council, Cheyenne, WY.

This book lists dozens of methods – their intended uses and potential abuses.



For its evaluations and analyses, the Brazos BBEST used:

1. **Indicators of Hydrologic Alteration Method** – provides ecologists and hydrologists with a tool to characterize and compare complex hydrologic regimes in ecologically meaningful terms.
2. **Target Fish Community Assessment** – describes a model fish community that serves as a target for river restoration, rehabilitation, or enhancement and as an endpoint for evaluating program success.
3. **Biological Response to Flow Correlation Method** – identifies correlations between biological response or habitat condition and flow-related variables.
4. **Floodplain Inundation Method** – determines flows to protect aquatic, riparian, wetland, and floodplain resources or compare alternative flow regimes.

- No study results were available from *IFIM*, *PHabSim* or *MesoHabSim* methods.

The BBEST also evaluated:

5. **Water quality in relation to discharge**
6. **Sediment transport in relation to flow regimes (Flushing flow: empirical, sediment transport modeling, and 'desktop' hydrologic methods)**
7. **Estuarine inflows, salinity, and potential responses of coastal marine organisms** (indicator taxa)

Research findings specifically useful for evaluation of Upper Brazos River near Seymour

Conner, J.V. and R.D. Suttkus. 1986. Zoogeography of freshwater fishes of the western Gulf slope. Pages 413-456 in C.H. Hocutt and E.O. Wiley, Editors. *The Zoogeography of North American Freshwater Fishes*. Wiley, New York.

Craven, S.W., J.T. Peterson, M.C. Freeman, T.J. Kwak, and E. Irwin. 2010. Modeling the relations between flow regime components, species traits, and spawning success of fishes in warmwater streams. *Environmental Management* 46:181-194.

Durham, B.W. and G.R. Wilde. 2006. Influence of stream discharge on reproductive success of a prairie stream fish assemblage. *Transactions of the American Fisheries Society* 135:1644-1653.

Durham, B.W. and G.R. Wilde. 2006. Asynchronous and synchrounous spawning by smalleye shiner Notoropis buccula from the Brazos River, Texas. *Ecology of Freshwater Fish* 17:528-541.

Durham, B.W. and G.R. Wilde. 2009a. Effects of streamflow and intermittency on the reproductive success of two broadcast-spawning cyprinid fishes. *Copeia* 2009:21-28.

Durham, B.W. and G.R. Wilde. 2009b. Population dynamics of the smalleye shiner, an imperiled cyprinid fish endemic to the Brazos River, Texas. *Transactions of the American Fisheries Society* 138:666-674.

Howells, R.G., R.W. Neck, and H.D. Murray. 1996. *Freshwater Mussels of Texas*. Texas Parks and Wildlife Press, Austin, TX, 224 pp.

Hubbs, C., R.J. Edwards, and G.P. Garrett. 2008. An annotated checklist of the freshwater fishes of Texas, with keys to identification of species. *Texas Journal of Science, Supplement* 43(4):1-56.

Perkin, J.S., C.S. Williams, and T.H. Bonner. 2009. Aspects of chub shiner *Notropis potteri* life history with comments on native distribution and conservation status. *American Midland Naturalist* 162:276-288.

Perkin, J.S. and K.B. Gido. 2011. Stream fragmentation thresholds for a reproductive guild of Great Plains fishes. *Fisheries* 36:371-383.

Rees, D.E., R.J. Carr, and W.J. Miller. (2005). *Plains Minnow (*Hybognathus placitus*): A Technical Conservation Assessment*. [Online]. USDA Forest Service, Rocky Mountain Region.

Wilde, G.R. and B.W. Durham. 2008. A life history model for peppered chub, a broadcast-spawning cyprinid. *Transactions of the American Fisheries Society* 137:1657-1666.

Brazos River at Seymour

	Winter (Nov, Dec, Jan, Feb)	Spring (Mar, Apr, May, Jun)	Summer (Jul, Aug, Sep, Oct)
Overbank Events	Qp: 16,800 cfs with Average Frequency 1 per 2 years Regressed Volume is 125,000 Duration Bound is 35		
High Flow Pulses	Qp: 10,400 cfs with Average Frequency 1 per year Regressed Volume is 74,100 Duration Bound is 29		
	Qp: 250 cfs with Average Frequency 1 per season Regressed Volume is 1,560 Duration Bound is 10	Qp: 4,730 cfs with Average Frequency 1 per season Regressed Volume is 30,500 Duration Bound is 20	Qp: 4,570 cfs with Average Frequency 1 per season Regressed Volume is 28,600 Duration Bound is 21
	Qp: 97 cfs with Average Frequency 2 per season Regressed Volume is 490 Duration Bound is 6	Qp: 2,000 cfs with Average Frequency 2 per season Regressed Volume is 12,000 Duration Bound is 15	Qp: 1,560 cfs with Average Frequency 2 per season Regressed Volume is 8,910 Duration Bound is 14
		Qp: 1,040 cfs with Average Frequency 3 per season Regressed Volume is 5,870 Duration Bound is 12	Qp: 800 cfs with Average Frequency 3 per season Regressed Volume is 4,290 Duration Bound is 11
		Qp: 560 cfs with Average Frequency 4 per season Regressed Volume is 2,960 Duration Bound is 10	Qp: 370 cfs with Average Frequency 4 per season Regressed Volume is 1,870 Duration Bound is 8
Base Flows (cfs)	46	35	32
	25	19	13
	10	7	4
Subsistence Flows (cfs)	1	1	1
	Nov, Dec, Jan, Feb	Mar, Apr, May, Jun	Jul, Aug, Sep, Oct
	Winter	Spring	Summer

Base Flow Levels	
	High (75th %ile)
	Medium (50th %ile)
	Low (25th %ile)

Pulse volumes are in units of acre-feet and durations are in days.

Period of record used : 1/1/1924 to 12/31/2010.

Episodic events are terminated when the volume or duration criteria are met, or when the flow drops below 42 cfs, or when the flow is below 152 cfs and the flow drops from one day to the next by less than 5%.

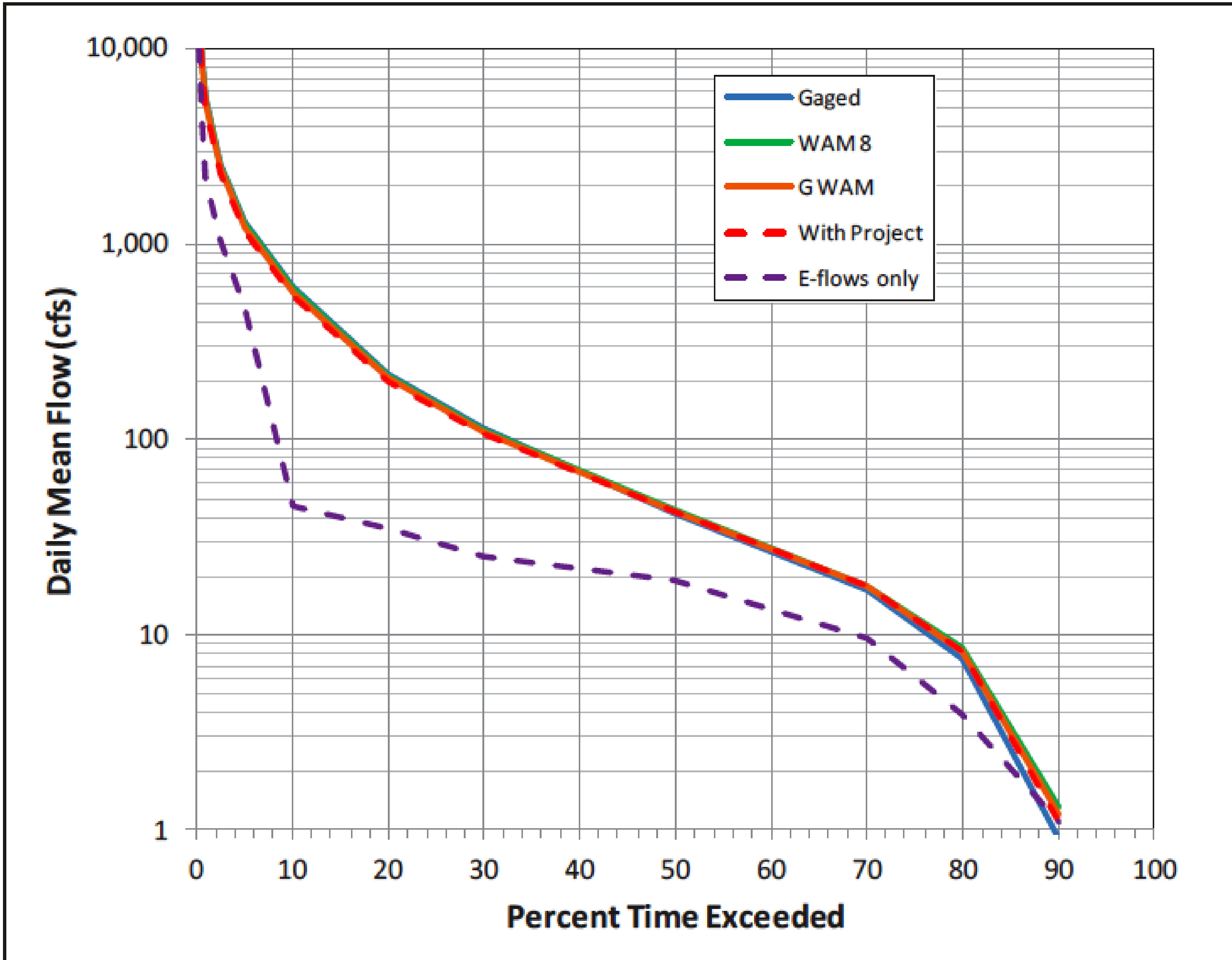
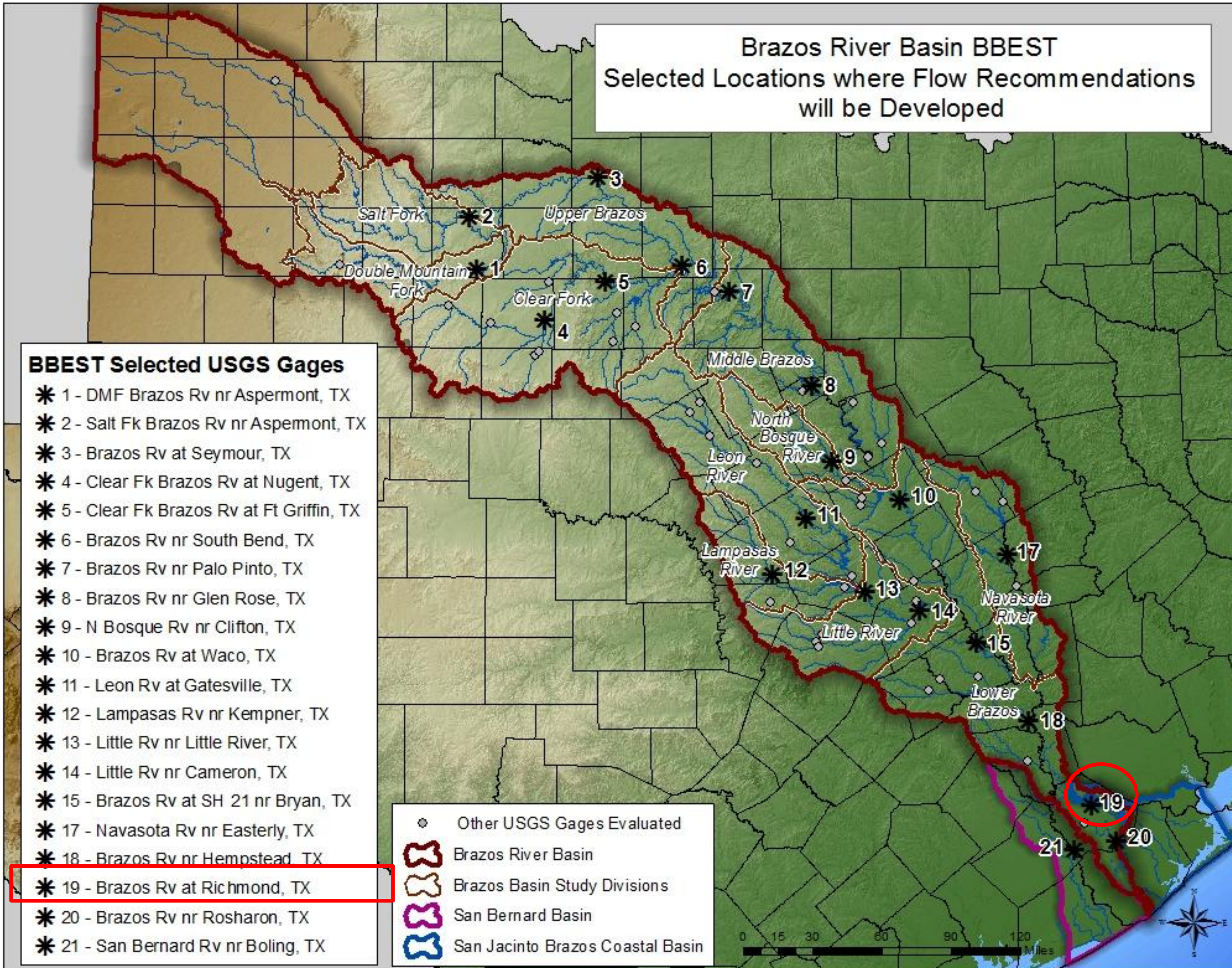
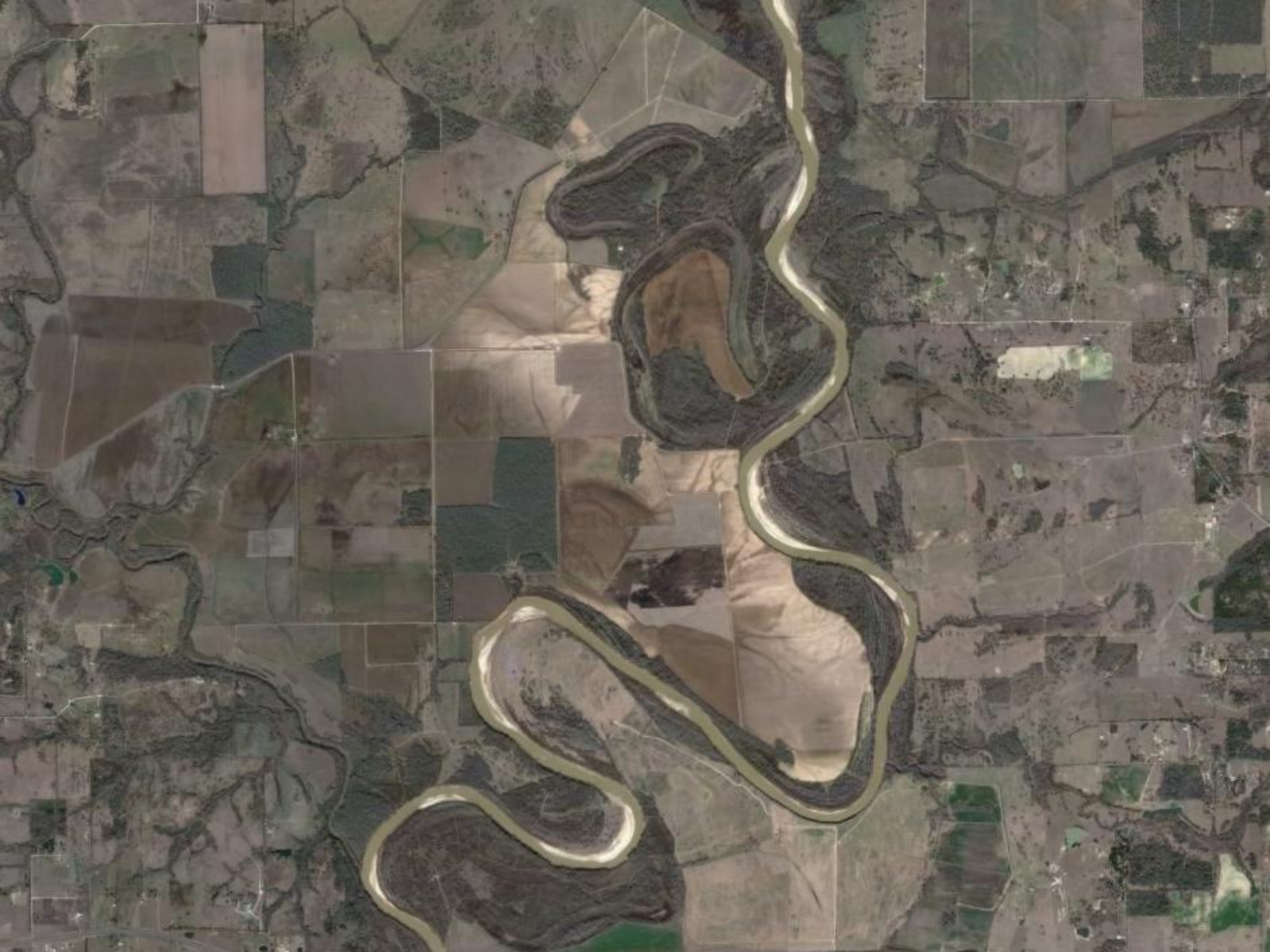
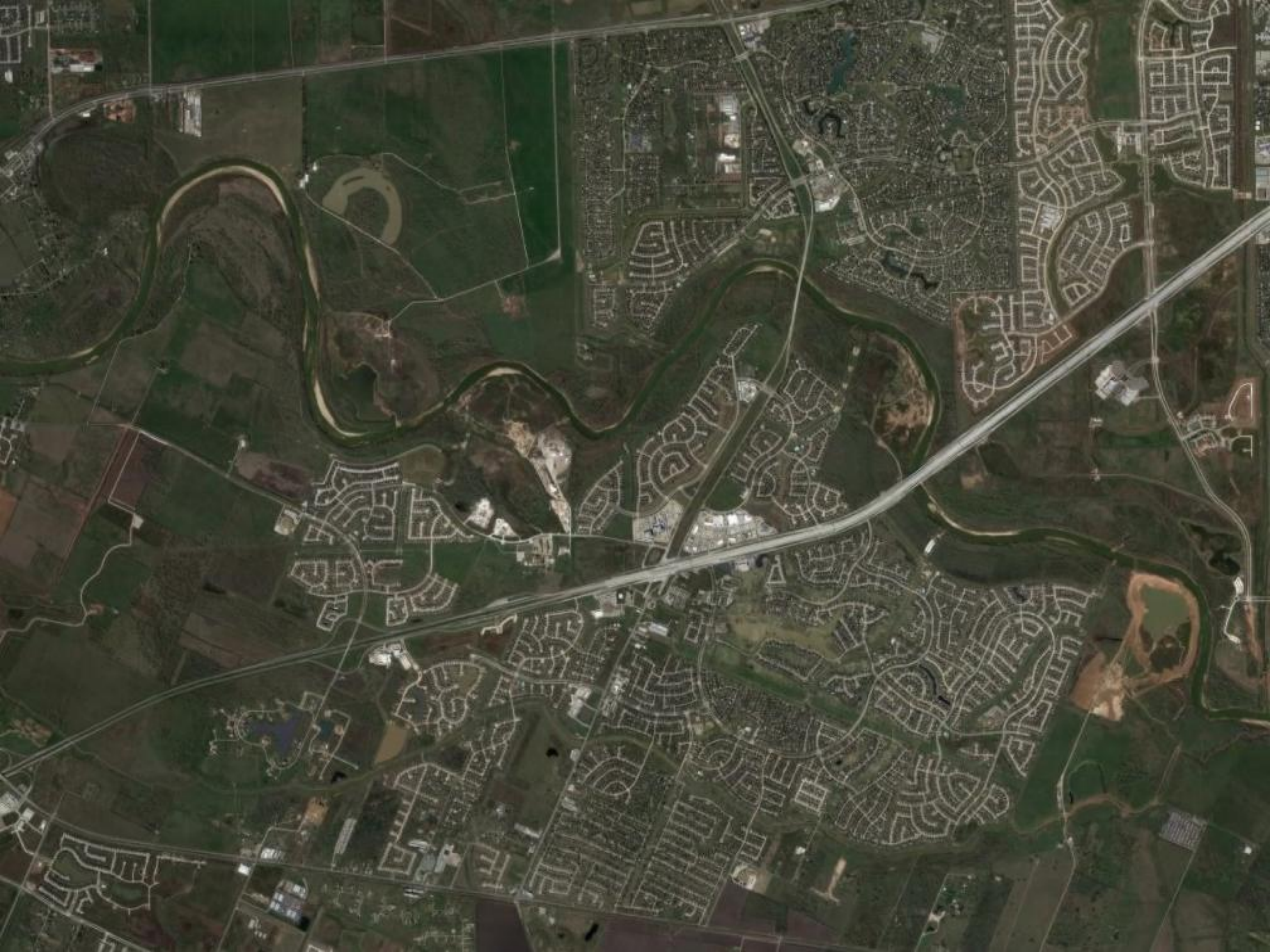


Figure 7.7. Flow duration curves for the Brazos River at Seymour.

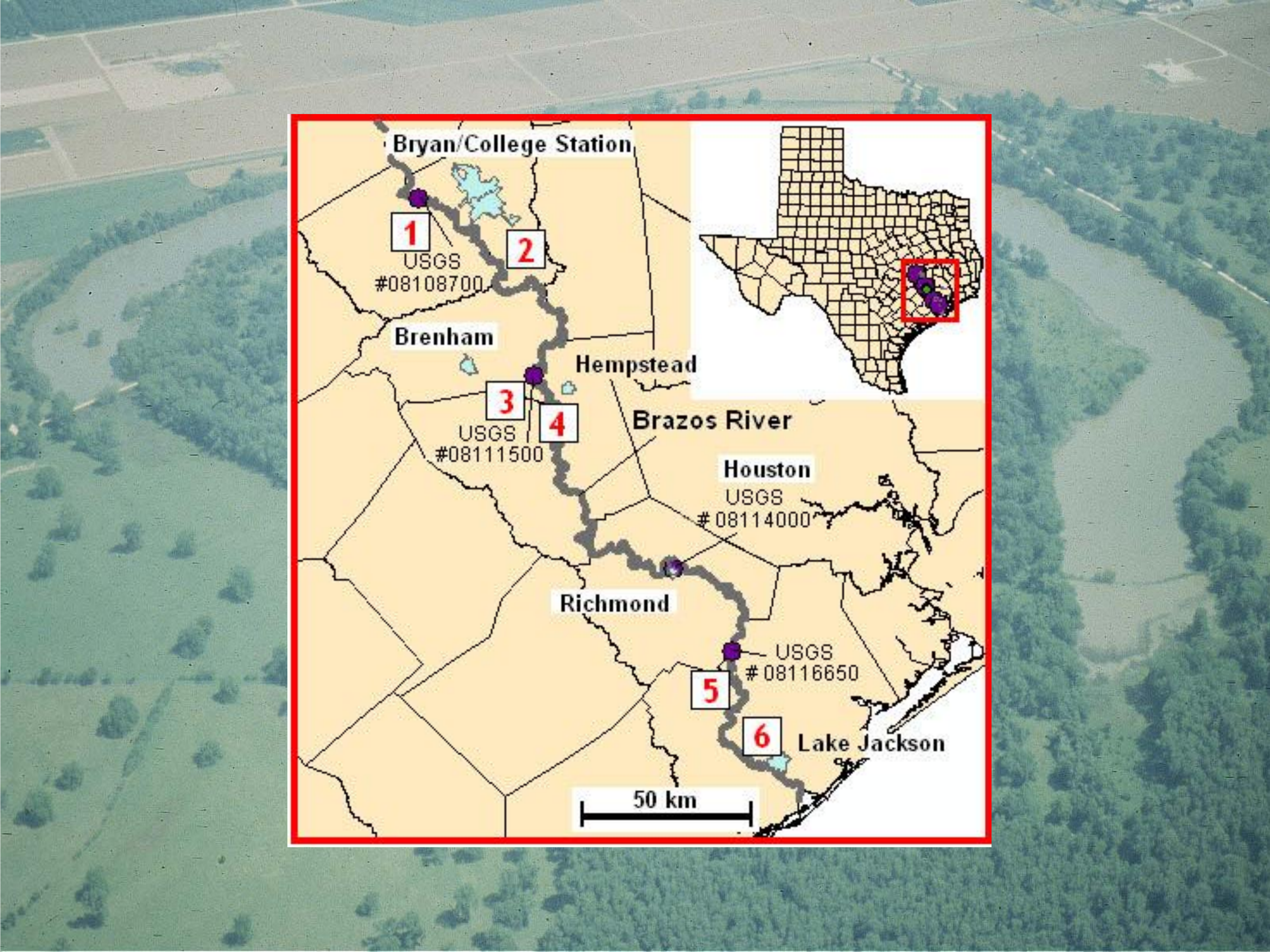
Average Annual Water and Sediment Yields		
	Average Annual Yield	
Hydrologic Scenarios	**Water** **Acre-Feet (% of Baseline)**	**Sediment** **Tons per Year (% of Baseline)**
BRAZOS RIVER AT SEYMOUR		
Historical Flows		
1940-1997 Gaged Flows	246,000 (102%)	296,000 (103%)
Simulated Flows		
WAM 8 Flows (Baseline)	242,000 (100%)	288,000 (100%)
G WAM	233,000 (96%)	262,000 (91%)
G WAM with Project	223,000 (92%)	233,000 (81%)
E Flow Only	93,400 (39%)	56,600 (20%)


Brazos River Basin BBEST
Selected Locations where Flow Recommendations will be Developed
BBEST Selected USGS Gages
1 - DMF Brazos Rv nr Aspermont, TX
2 - Salt Fk Brazos Rv nr Aspermont, TX
3 - Brazos Rv at Seymour, TX
4 - Clear Fk Brazos Rv at Nugent, TX
5 - Clear Fk Brazos Rv at Ft Griffin, TX
6 - Brazos Rv nr South Bend, TX
7 - Brazos Rv nr Palo Pinto, TX
8 - Brazos Rv nr Glen Rose, TX
9 - N Bosque Rv nr Clifton, TX
10 - Brazos Rv at Waco, TX
11 - Leon Rv at Gatesville, TX
12 - Lampasas Rv nr Kempner, TX
13 - Little Rv nr Little River, TX
14 - Little Rv nr Cameron, TX
15 - Brazos Rv at SH 21 nr Bryan, TX
17 - Navasota Rv nr Easterly, TX
18 - Brazos Rv nr Hempstead, TX
19 - Brazos Rv at Richmond, TX
20 - Brazos Rv nr Rosharon, TX
21 - San Bernard Rv nr Boling, TX
Other USGS Gages Evaluated
Brazos River Basin
Brazos Basin Study Divisions
San Bernard Basin
San Jacinto Brazos Coastal Basin
Salt Fork
Upper Brazos
Double Mountain Fork
Clear Fork
Middle Brazos
North Bosque River
Leon River
Lampasas River
Little River
Navasota River
Lower Brazos
0 15 30 60 90 120
Miles





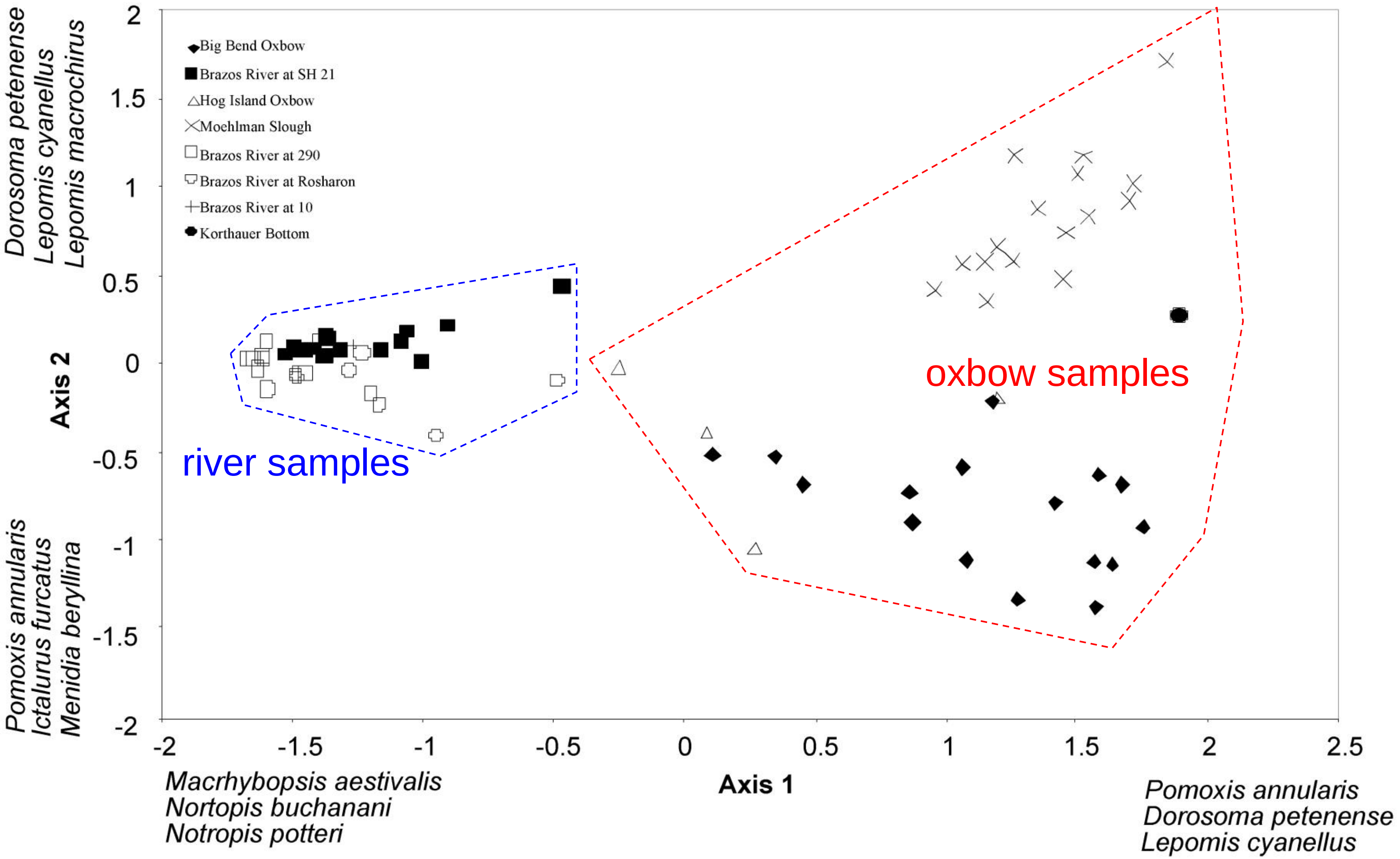
Moehlman’s Slough, oxbow in Burleson co.



Bryan/College Station
1
USGS
#08108700
2
Brenham
Hempstead
3
4
USGS
#08111500
Brazos River
Houston
USGS
08114000
Richmond
USGS
08116650
5
6
Lake Jackson
50 km

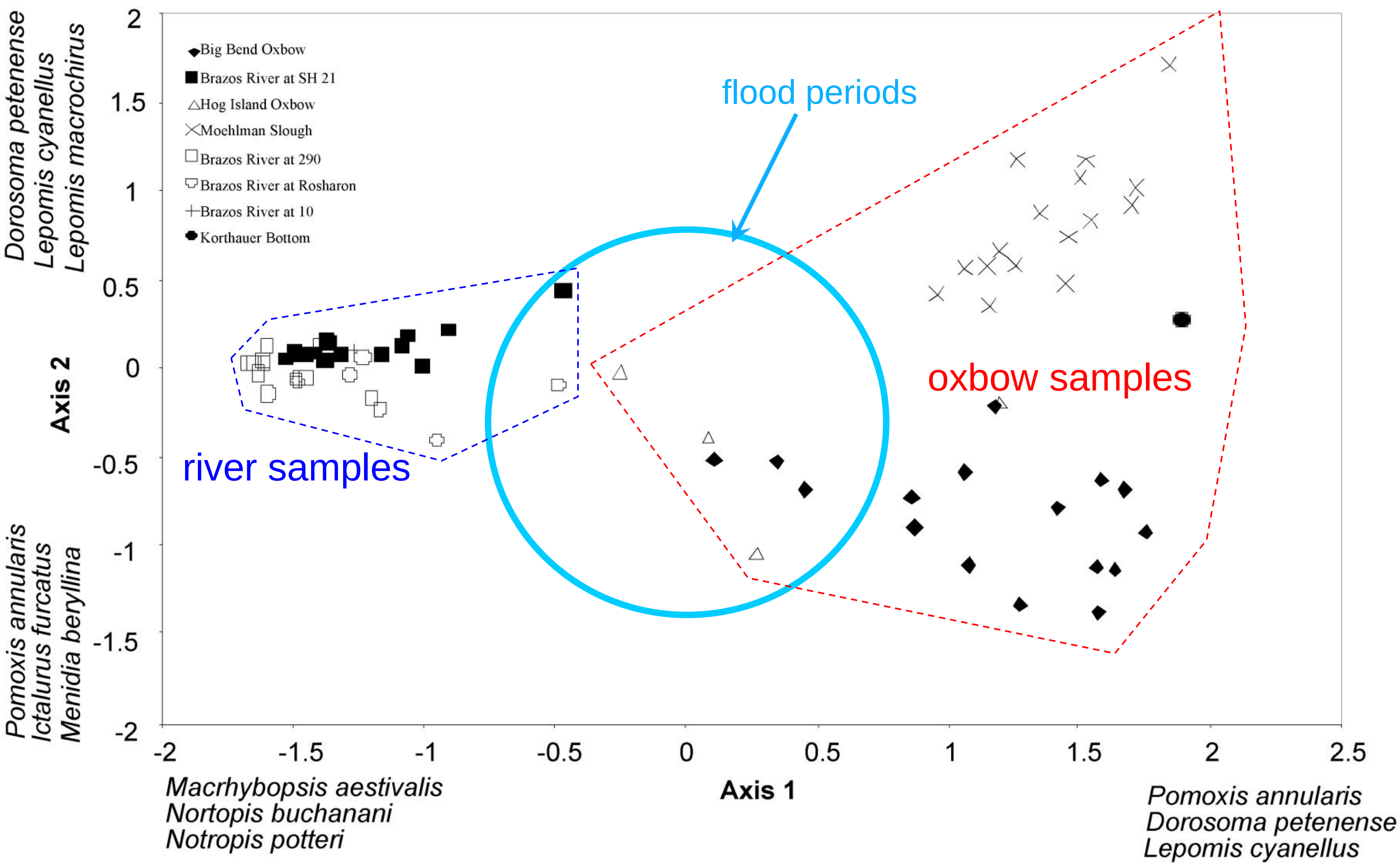
Oxbow	Flow to Connect (cfs)	Number of Connections 1984-1994	1994-2004
Hog Island	3,625	61	68
Big Bend	20,000	32	41
Korthauer Bottom	20,500	32	50
Moehlman Slough	45,000	14	12
Cutoff Lake	76,200	2	3
Horseshoe Lake	99,000	1	0

Structure of river channel and oxbow lake fish assemblages



CA using seine CPUE data for fishes

During floods there is exchange of fishes between river and oxbows



CA using seine CPUE data for fishes

Lower Brazos River (reach below the mouth of the Bosque River to the coast): Moderate fish assemblage integrity; the majority of the fish community remains intact. Loss of at least one fluvial specialist (smalleye shiner, *Notropis buccula*) and declines in populations of several other fluvial specialists and increases in abundance of habitat generalists, such as bluegill sunfish (*Lepomis macrochirus*), suggest community changes associated with flow modifications.

December 19, 2007, Receding HFP event 5,910 cfs – upstream (left), downstream (right)

Research findings specifically useful for evaluation of Lower Brazos River near Richmond

Bonner, T. and D.T. Runyan. 2007. *Fish Assemblage Changes in Three Western Gulf Slope Drainages*. Final Report to the Texas Water Development Board (2205-483-033), TWDB, Austin, TX, 46 pp.

Chowdury, A.H., T. Osting, J. Furnans, and R. Mathews. 2010. Groundwater-surface water interaction in the Brazos River Basin: Evidence from lake connection history and chemical isotopic compositions. Report 375, Texas Water Development Board, Austin, 61 pp.

Coffman, D.K., G. Malstaff, and F.T. Heitmuller. 2011. *Characterization of Geomorphic Units in the Alluvial Valleys and Channels of Gulf Coastal Plain Rivers in Texas, with Examples from the Brazos, Sabine, and Trinity Rivers, 2010*. U.S. Geological Survey Scientific Investigations Report 2011–5067. USGS, Austin, TX, 31 pp.

Conner, J.V. and R.D. Suttkus. 1986. Zoogeography of freshwater fishes of the western Gulf slope. Pages 413-456 in C.H. Hocutt and E.O. Wiley, Editors. *The Zoogeography of North American Freshwater Fishes*. Wiley, New York.

Duke, J.R. 2011. Riparian Productivity in Relation to Stream Dynamics Along Two Rivers: San Antonio and Brazos, in Central/South Texas. Report to Texas Water Development Board, Contract #1000011020, 116 pp.

Dunn, D.D. and T.H. Raines. 2001. *Indications and Potential Sources of Change in Sand Transport in the Brazos River, Texas*. U.S. Geological Survey Water-Resources Investiga-tions Report 01–4057, 32 pp.

Durham, B.W. and G.R. Wilde. 2006. Influence of stream discharge on reproductive success of a prairie stream fish assemblage. *Transactions of the American Fisheries Society* 135:1644-1653.

Durham, B.W. and G.R. Wilde. 2009a. Effects of streamflow and intermittency on the reproductive success of two broadcast-spawning cyprinid fishes. *Copeia* 2009:21-28.

Gillespie, B.M. and J.R. Giardino. 1997. The nature of channel planform change: Brazos River, Texas. *Texas Journal of Science* 49:109-142.

Gooch, T. and D. Dunn. 2001. *Naturalized Flow Estimates for the Brazos River Basin and the San Jacinto-Brazos Coastal Basin*. Report to the Texas Natural Resource Conservation Commission, Austin, TX, 523 pp.

Heitmuller, F.T. and L.E. Greene. 2009. *Historical Channel Adjustment and Estimates of Selected Hydraulic Values in the Lower Sabine River and Lower Brazos River Basins, Texas and Louisiana*. Scientific Investigations Report 2009-5174, U.S. Geological Survey, Reston, VA.

Howells, R.G., R.W. Neck, and H.D. Murray. 1996. *Freshwater Mussels of Texas*. Texas Parks and Wildlife Press, Austin, TX, 224 pp.

Hubbs, C., R.J. Edwards, and G.P. Garrett. 2008. An annotated checklist of the freshwater fishes of Texas, with keys to identification of species. *Texas Journal of Science, Supplement* 43(4):1-56.

Karatayev, A.Y. and L.E. Burlakova. 2008. *Distributional Survey and Habitat Utilization of Freshwater Mussels*. Contract No. 0604830631. Texas Water Development Board, Austin, TX, 47 pp.

Kirkpatrick, J. 1979. *Intensive Survey of the Brazos River, Segment 1201 (Hydrology, Field Measurements, Water Chemistry, Sediment Chemistry, Biology)*. IS-4. Texas Department of Water Resources. Austin, TX, 83 pp.

Labay, B. 2010. The influence of land use, zoogeographic history, and physical habitat on fish community diversity in the lower Brazos watershed. Unpublished M.S. Thesis. Texas State University, San Marcos, TX.

Li, R.Y. and F.P. Gelwick. 2005. The relationship of environmental factors to spatial and temporal variation of fish assemblages in a floodplain river in Texas, USA. *Ecology of Freshwater Fish* 14:319-330.

Osting, T., R. Mathews, and B. Austin. 2004a. *Analysis of Instream Flows for the Lower Brazos River– Hydrology, Hydraulic, and Fish Habitat Utilization*. TWDB Report to US Army Corps of Engineers, Contract W45XMA11296580/TWDB 2001-REC-015, 159 pp., with 16 appendices.

Osting, T., J. Furnans, and R. Mathews. 2004b. *Surface Connectivity between Six Oxbow Lakes and the Brazos River, Texas.* Report to Texas Water Development Board, Surface Water Resource Division, Austin, TX, 63 pp.

Perkin, J.S., C.S. Williams, and T.H. Bonner. 2009. Aspects of chub shiner *Notropis potteri* life history with comments on native distribution and conservation status. *American Midland Naturalist* 162:276-288.

Randklev, C.R., J.H. Kennedy, and B. Lundeen. 2009. *Distributional Survey and Habitat Utilization of Freshwater Mussels (Family Unionidae) in the Lower Brazos and Sabine River Basins*. Contract No. 0704830778. Texas Water Development Board, Austin, TX, 57 pp.

Roach, K. and K.O. Winemiller. 2011. Diurnal change of sandbank fish and shrimp assemblages in a temperate lowland river. *Transactions of the American Fisheries Society* 140:84-90.

Robertson, C.R., S.C. Zeug, and K.O. Winemiller. 2008. Associations between hydrological connectivity and resource partitioning among sympatric gar species (Lepisosteidae) in a Texas river and associated oxbows. *Ecology of Freshwater Fish* 17:119-129.

Rodriguez, A.B., M.D. Hamilton, and J.B. Anderson. 2000. Facies and evolution of the modern Brazos delta, Texas: wave versus flood influence. *Journal of Sedimentary Research* 70:283-295.

Schneider, K. and K.O. Winemiller. 2008. Structural complexity of woody debris patches influences fish and macroinvertebrate species richness in a temperate floodplain river. *Hydrobiologia* 610:235-244.

Wilde, G.R. and B.W. Durham. 2008. A life history model for peppered chub, a broadcast-spawning cyprinid. *Transactions of the American Fisheries Society* 137:1657-1666.

Williams, C.S. 2011. Life history characteristics and larval drift patterns of obligate riverine species in the Lower Brazos River, Texas. Unpublished Ph.D. Dissertation, Texas State University, San Marcos, Texas.

Winemiller, K.O. 1996. Factors driving spatial and temporal variation in aquatic floodplain food webs. Pages 298-312, In: G.A. Polis and K.O. Winemiller, Editors. *Food Webs: Integration of Patterns and Dynamics*. Chapman and Hall, New York.

Winemiller, K.O., S. Tarim, D. Shormann, and J.B. Cotner. 2000. Spatial variation in fish assemblages of Brazos River oxbow lakes. *Transactions of the American Fisheries Society* 129:451-468.

Winemiller, K.O., T. Bonner, F.P. Gelwick, S. Zeug, and C. Williams. 2004. *Response of Oxbow Lake Biota to Hydrologic Exchanges with the Brazos River Channel*. Final Project (2003-483-493, 2003-483-003) Report to the Texas Water Development Board, 59 pp.

Winemiller, K.O., N.K. Lujan, R.N. Wilkins, R.T. Snelgrove, A.M. Dube, K.L. Skow, and A.G. Snelgrove. 2010. *Status of Freshwater Mussels in Texas*. Texas A&M Institute of Renewable Natural Resources, College Station, TX.

Zeng, F.-W., C.A. Masiello, and W.C. Hockaday. 2011. Controls on the origin and cycling of riverine dissolved inorganic carbon in the Brazos River, Texas. *Biogeochemistry* 104:275-291.

Zeug, S.C. and K.O. Winemiller. 2007. Ecological correlates of fish reproductive activity in floodplain rivers: a life history-based approach. *Canadian Journal of Fisheries and Aquatic Sciences* 64:1291-1301.

Zeug, S.C. and K. O. Winemiller. 2008a. Relationships between hydrology, spatial heterogeneity, and fish recruitment dynamics in a temperate floodplain river. *River Research and Applications* 24:90-102.

Zeug, S.C. and K.O. Winemiller. 2008b. Evidence supporting the importance of terrestrial carbon in a large-river food web. *Ecology* 89:1733-1743.

Zeug, S.C., Winemiller, K.O., and S. Tarim. 2005. Response of Brazos River oxbow fish assemblages to patterns of hydrologic connectivity and environmental variability. *Transactions of the American Fisheries Society* 134:1389-1399.

Zeug, S.C., D. Peretti, and K.O. Winemiller. 2009. Movement into floodplain habitats by gizzard shad (*Dorosoma cepedianum*) revealed by dietary and stable isotope analyses. *Environmental Biology of Fishes* 84:307-314.

Brazos River near Richmond

	Winter				Spring				Summer			
Overbank Events	Qp: 68,100 cfs with Average Frequency 1 per 2 years Regressed Volume is 1,487,000 Duration Bound is 41											
High Flow Pulses	Qp: 51,600 cfs with Average Frequency 1 per year Regressed Volume is 1,019,000 Duration Bound is 35											
	Qp: 24,600 cfs with Average Frequency 1 per season Regressed Volume is 383,000 Duration Bound is 23				Qp: 35,000 cfs with Average Frequency 1 per season Regressed Volume is 617,000 Duration Bound is 29				Qp: 12,900 cfs with Average Frequency 1 per season Regressed Volume is 144,000 Duration Bound is 15			
	Qp: 12,400 cfs with Average Frequency 2 per season Regressed Volume is 150,000 Duration Bound is 16				Qp: 16,300 cfs with Average Frequency 2 per season Regressed Volume is 215,000 Duration Bound is 19				Qp: 5,430 cfs with Average Frequency 2 per season Regressed Volume is 46,300 Duration Bound is 10			
	Qp: 6,410 cfs with Average Frequency 3 per season Regressed Volume is 60,600 Duration Bound is 11				Qp: 8,930 cfs with Average Frequency 3 per season Regressed Volume is 94,000 Duration Bound is 13				Qp: 2,460 cfs with Average Frequency 3 per season Regressed Volume is 16,400 Duration Bound is 6			
Base Flows (cfs)	3,310				3,980				2,190			
	1,650				2,140				1,330			
	990				1,190				930			
Subsistence Flows (cfs)	550				550				550			
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
	Winter				Spring				Summer			

Base Flow Levels	
	High (75th %ile)
	Medium (50th %ile)
	Low (25th %ile)

Pulse volumes are in units of acre-feet and durations are in days.

Period of record used : 1/1/1923 to 12/31/2010.

Episodic events are terminated when the volume or duration criteria are met, or when the flow drops below 1260 cfs, or when the flow is below 8430 cfs and the flow drops from one day to the next by less than 5%.

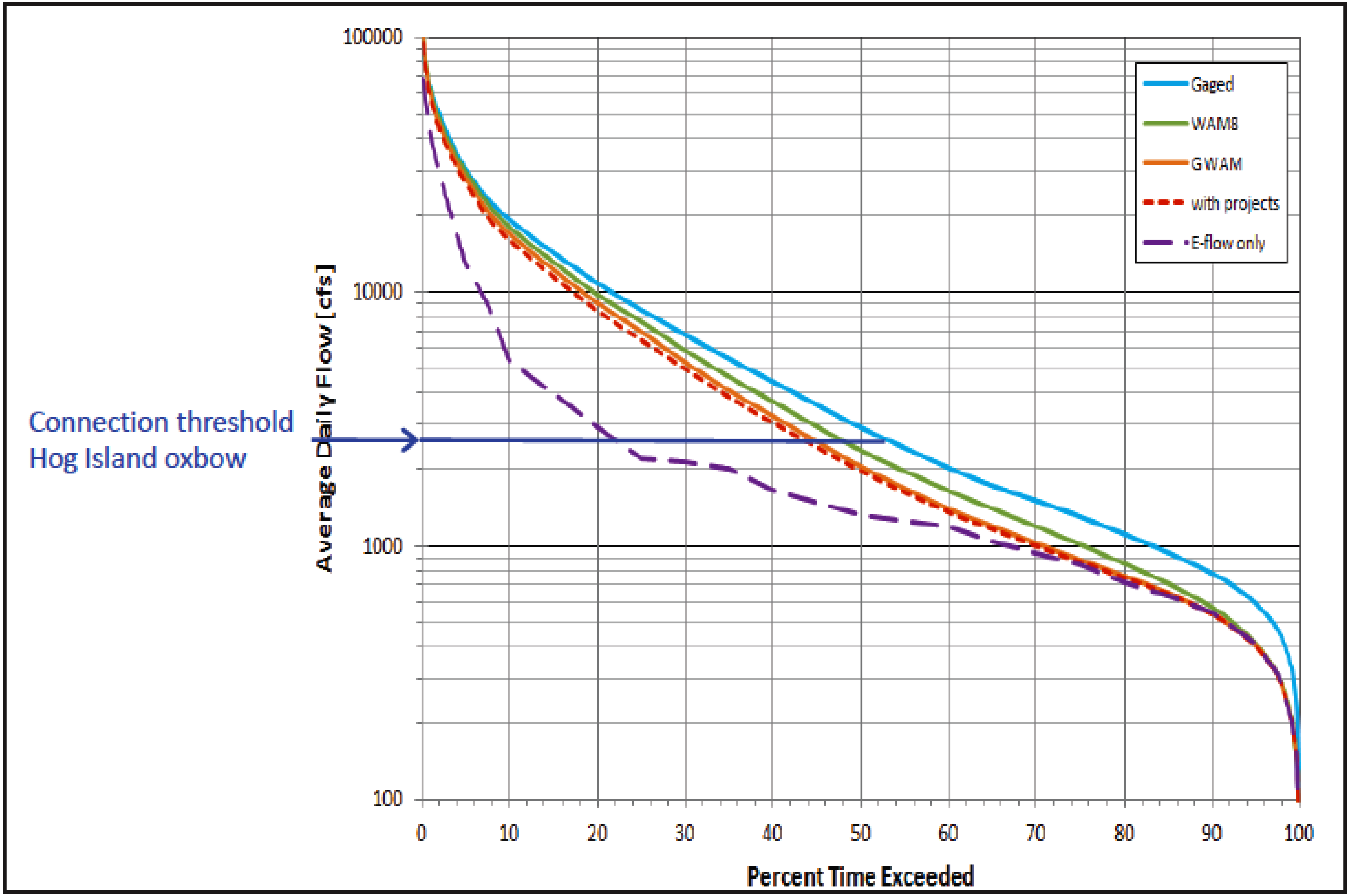


Figure 7.13. Flow threshold for lateral connection between the Brazos River channel and Hog Island oxbow in relation to the flow duration curve at the Richmond gage under five flow scenarios.

Average Annual Water and Sediment Yields		
	Average Annual Yield	
Hydrologic Scenarios	Water Acre-Feet (% of Baseline)	Sediment Tons per Year (% of Baseline)
BRAZOS RIVER AT RICHMOND		
Historical Flows		
1940-1997 Gaged Flows	5,480,000 (107%)	3,010,000 (85%)
Simulated Flows		
WAM 8 Flows (Baseline)	5,130,000 (100%)	3,530,000 (100%)
G WAM	4,780,000 (93%)	3,190,000 (90%)
G WAM with Projects	4,580,000 (89%)	2,930,000 (83%)
E Flow Only	2,340,000 (46%)	797,000 (23%)

Geomorphology and Sediment Transport Analysis

- Historical data indicates both locations experiencing modest geomorphic change (channel widening)**(correction: channel incision)**
- Transport formulas all significantly underestimate transport at the larger discharges
- Channels at both sites have not reached dynamic equilibrium
- Cannot determine if a new project subject to flow alterations would move channel towards stability or increase instability
- E-flow only regimes, as recommended, provide approximately 80% **(correction: 20 – 23%)** of the annual average sediment yield compared to baseline conditions

Hydrologic Scenarios

- Gaged – daily flows from 1940 – 1997
- WAM – monthly flows intended to represent current conditions with respect to water rights, considering full utilization of all rights
  - WAM 8 –actual, current diversion rates
  - G WAM – WAM model adjusted to represent conditions expected to be in place in 2060
- With Projects – conditions expected in the future if various water supply projects are completed
- E-flow Only – environmental flow recommendations only

With Projects

- Seymour
  – Double Mountain Fork-West Reservoir
- Richmond
  – Double Mountain Fork-West Reservoir
  – Millican Panther Creek Reservoir
- Used estimated daily project outflows based on daily inflows and projected reservoir capacity

E-Flows Only Scenario

- Supposes “infinite infrastructure”
  - Capacity to divert or impound all water in excess of the e-flow recommendations
  - In reality, projects have limits on diversion rates or total volume impounded
- Does not consider downstream water rights
  - Some water that could physically be diverted via a new project is already legally obligated downstream

Environmental risk management when limited by scientific knowledge and uncertainty

from J. A. Wiens, *Bulletin of the British Ecological Society*

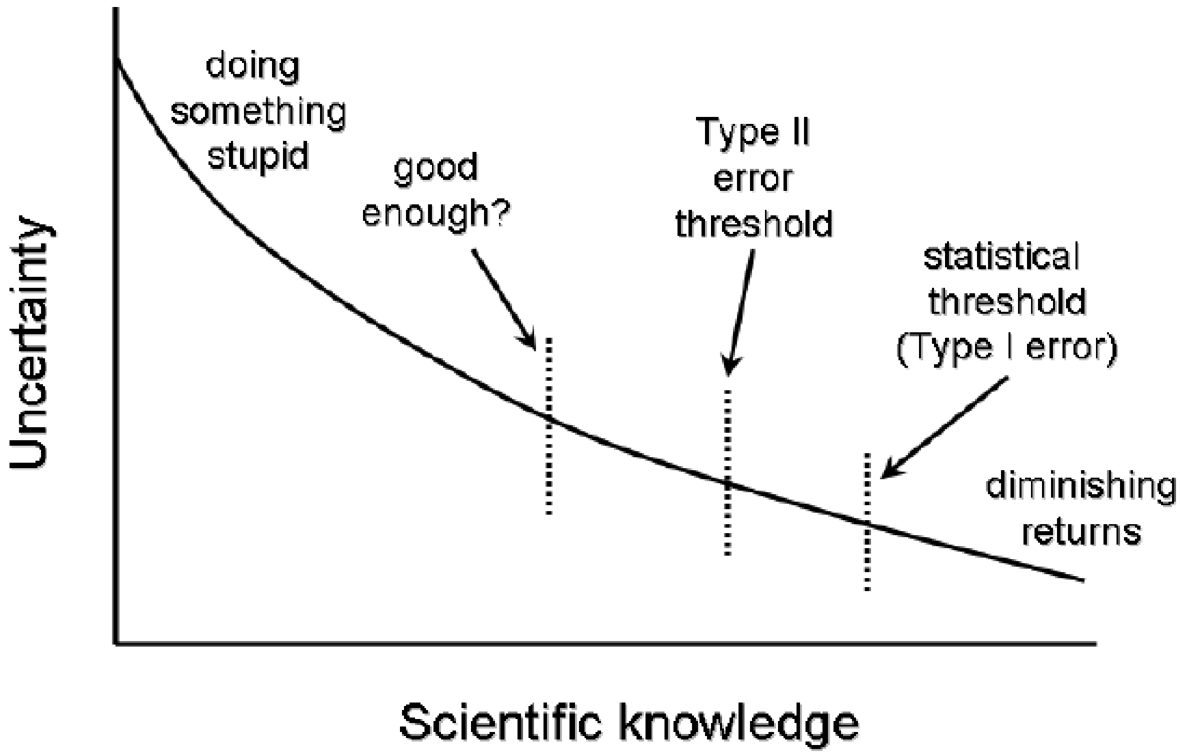


Figure 1. Uncertainty decreases as some function of increasing scientific knowledge. The statistical thresholds that define Type I errors (the likelihood of incorrectly inferring a relationship between variables when none exists) and Type II errors (the likelihood of incorrectly concluding no relationship when in fact one exists) are generally well established. The location of the “good enough” threshold is more nebulous, and shifts toward the right as the costs of making a mistake become greater.

Example of E-flows derived from habitat availability models – Nueces BBEST

Laguna – % Max WUA, 0.5 Threshold

How much is "enough"? – we used 75% for base flows, 20% for subsistence